52. IWK

Internationales Wissenschaftliches Kolloquium
International Scientific Colloquium

PROCCEDINGS | 10 - 13 September 2007

FACULTY OF COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME II

Session 6 - Environmental Systems: Management and Optimisation

Session 7 - New Methods and Technologies for Medicine and Biology

Session 8 - Embedded System Design and Application

Session 9 - Image Processing, Image Analysis and Computer Vision

Session 10 - Mobile Communications

Session 11 - Education in Computer Science and Automation

TECHNISCHE UNIVERSITÄT
ILMENAU

Bibliografische Information der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbiografie; detaillierte bibliografische Daten sind im Internet über **http://dnb.ddb.de** abrufbar.

ISBN 978-3-939473-17-6

Impressum

Herausgeber:	Der Rektor der Technischen Universität Ilmenau Univ.-Prof. Dr. rer. nat. habil. Peter Scharff
Redaktion:	Referat Marketing und Studentische Angelegenheiten Kongressorganisation Andrea Schneider Tel.: +49 3677 69-2520 Fax: +49 3677 69-1743 e-mail: kongressorganisation@tu-ilmenau.de
Redaktionsschluss:	Juli 2007
Verlag:	Technische Universität Ilmenau/Universitätsbibliothek Universitätsverlag Ilmenau Postfach 10 05 65 98684 Ilmenau www.tu-ilmenau.de/universitaetsverlag
Herstellung und Auslieferung:	Verlagshaus Monsenstein und Vannerdat OHG Am Hawerkamp 31 48155 Münster www.mv-verlag.de
Layout Cover:	www.cey-x.de
Bezugsmöglichkeiten:	Universitätsbibliothek der TU Ilmenau Tel.: +49 3677 69-4615 Fax: +49 3677 69-4602

Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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J.C. Ferreira / A.A. Fernandes / A.D. Santos

Modelling and Rapid Prototyping an Innovative Ankle-Foot Orthosis to Correct Children Gait Pathology

ABSTRACT

Nowadays, the conventional Ankle Foot Orthosis (AFO) models existents in the market cannot be use by about 30% of the patients, and have some limitations to all the users, because should be custom-made. Knowing these problems the work developed has a main goal to design a new type of AFO, adaptable as far as possible to all the needs of the children's patients to have a normal life. This project is a partnership created between Instituto Superior Técnico, Departamento de Engenharia Mecânica and the children's Hospital D. Estefânia having as objective to develop and model an Ankle Foot Orthosis applied to children with gait pathology considering neurological problems such as drop foot stroke, spinal cord injuries (example: Spina Bífida), cerebral palsy, multiple sclerosis and trauma. The light weight AFO developed has in consideration all the patient needs, and a new concept idea of orthosis, attended to achieve the standardization of all possible components, never forgetting that always exist some personalised components that are tailored for specific persons. The design and concept development of a lightweight orthosis for the human lower limb that could comfortably provide plantar flexion and dorsiflexion energy during walking was accomplished. With all the improvements that are achieved is possible to have a larger target of people with pathological gait using these innovative AFO's products, which could allows increasing their comfort.

INTRODUCTION

There are millions of individuals with gait disabilities, requiring either rehabilitation or permanent assistance. Passive dynamic ankle-foot orthosis (AFOs) are often prescribed to improve gait performance for those with various neuromuscular disorders. Patients with various neuromuscular disorders often lose control and strength in their lower-limbs, which impairs their mobility. Drop foot pathology consists of the inability to properly lift the foot due to weakness or non-functioning dorsiflexor muscles. The current assistive technology for drop foot is a mechanical brace called an Ankle Foot Orthosis (AFO), which has been gaining increased usage over the last few years [1]. Recent biomechanical analyses of AFO's have shown an increase in walking speed and overall gait performance for patients with post-polio syndrome [2, 3]. Designs and materials used for AFO's range from simple polypropylene braces to advanced custom carbon composite fibber designs. AFO's design varies in the shape and length of the foot component as well as the stiffness and length of the tibial component depending on the desired functional outcomes. Rapid prototyping is an ideal technology for AFO development and manufacture because of its inherent customizing capabilities, which make fabrication of subject-specific AFO's feasible. In addition, the rapid prototyping has already been successfully used in the fabrication of prosthetic sockets for lower limb amputees [4]. The storage and release of elastic energy within the structure of passive dynamic AFO's is an important design characteristic that helps compensate for the neuromuscular disorders. During walking, elastic parts of the AFO deforms elastically under the influence of the body weight, thus storing elastic energy. During the second half of the stance when the AFO is unloaded, the AFO releases the stored energy to help satisfy the energetic demands of walking [5]. Although AFO's offer some biomechanical benefits, there are many disadvantages that can be improved on [6].

The main contribution of this research work is to apply ankle biomechanics, engineering principles and current rapid prototyping technology to develop an improved adaptive and autonomous system to assist drop foot gait.

MODELLING THE ANKLE-FOOT ORTHOSIS

The design model of the ankle-foot orthosis (AFO) consists of ten parts, including a foot section made in thin-polymer material. A light leg section articulately attached to the foot section on each side of the ankle by two rotational mechanical axes in order to facilitate dorsiflexion. The leg section has a two flanged rim-frames linked by two carbon composite bars overlapping the upper edge of the foot section. The overlap provides a stop for the backward movement of the leg section around the articulation (flexible joint) axe, thus limiting plantar flexion and drop-foot. Two elastic material parts store and release the elastic energy within the structure of the passive dynamic AFO. One metallic rear bar limits the foot rotational angular movement when walking. The AFO's Design Model and the constitutive parts are shown in figure 1.

Figure 1: AFO's Design Model and constitutive parts.

FEM ANALYSIS OF THE ANKLE-FOOT ORTHOSIS

The stress and strain of the main components of the AFO was investigated by Finite Element Method analysis. The critical situation occurs for an excessive dorsiflexion during the initial contact that needs a functional limitation. This limit function is of importance to prevent knee flexion with a incorrect posture and with inclination of the leg, which promotes an extraordinary muscular effort and consequently a great fatigue with exhaustion.

The stress and strain FEM analysis of the AFO's light leg section articulately attached to the foot section is shown in figure 2.

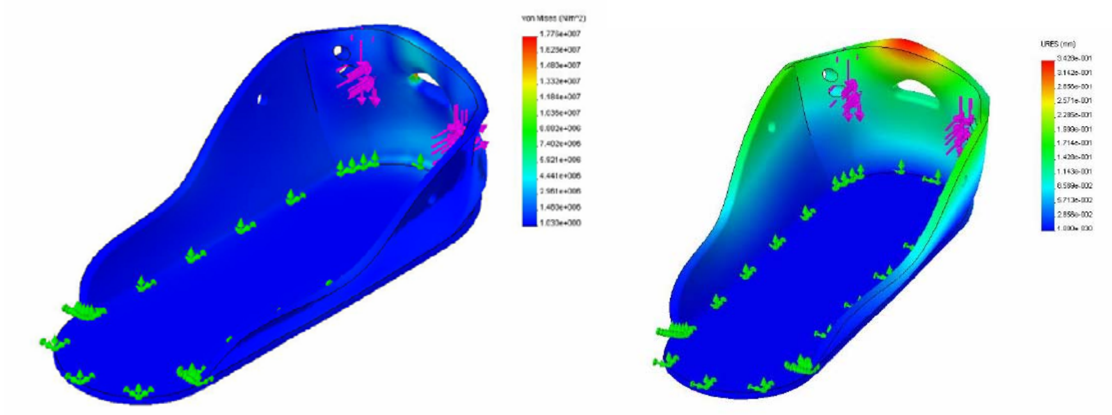

Figure 2: Von Mises stress analysis and strain analysis of AFO's foot component.

The FEM analysis allows identifying a critical Von-Mises stress located near the open hole utilised to anchorage the blocking belt with an average value of 17,8

MPa. The maximum part deformation is also located at the rear of the foot part in the vicinity of the hole utilized to fix the blocking belt.

The stress and strain FEM analysis of the AFO’s light leg section articulately attached to the foot section is shown in figure 3.

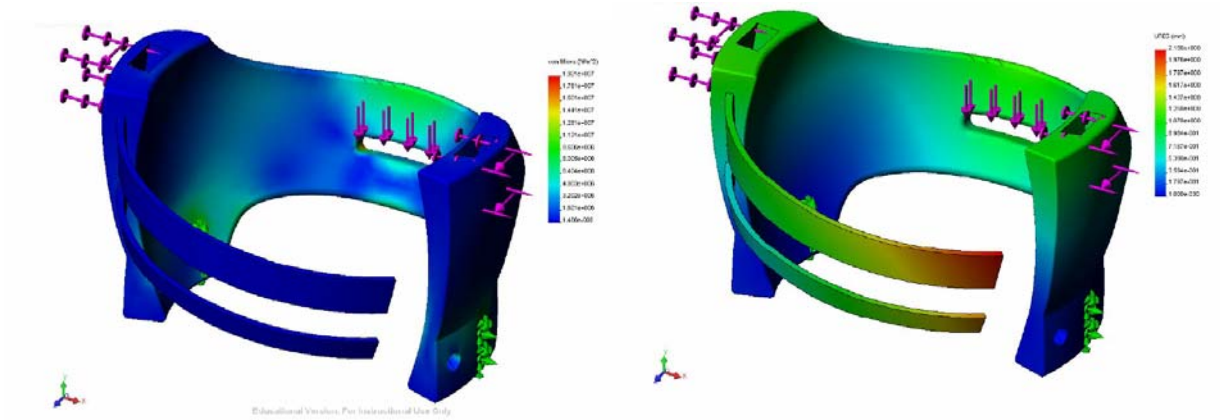

Figure 3: Von Mises stress analysis and strain analysis of AFO’s leg section articulately.

Analysing these figures for an applied load in the order of 250N and a tension strength factor owing the actuating angles at the oval extremities could be verified that the critical zones, with higher tension values attain 19MPa that is inferior to the tensile strength – 21MPa, and are located in the anchorage zone of the blockage band. In the constrains neighbourhood there are also tension values with a magnitude in the order of 11 MPa since in this zones the part is fixed, i.e. where the load reactions are located. The maximum strains attain 1, 25 mm where the blockage band is fixed, i.e. where is applied a load in the order of 250N. For the other part zones the deformations are insignificant. The stress and strain FEM analysis of the AFO’s upper leg section is shown in figure 4.

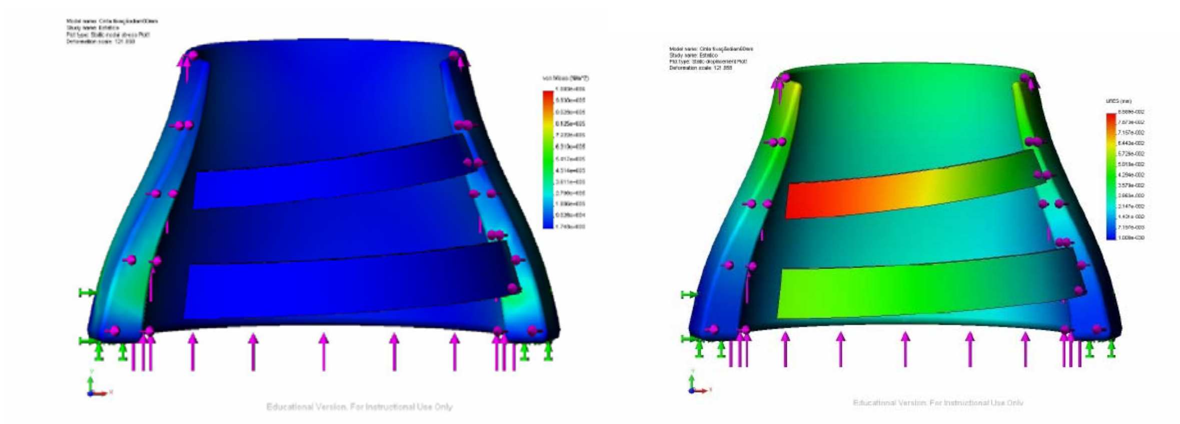

Figure 4: Von Mises stress analysis and strain analysis of AFO’s leg section.

The maximum Von-Mises stress values registered are in the order of 1MPa and are located in the constrict part zone. In spite off this stress value is considerably inferior to the material tensile strength. The maximum values of the Von-Mises strain analysis indicates that the deformation values are reduced in the order of 0,05mm at the top zone of the fixation belt.

AFO PROTOTYPES MADE BY RP TECHNOLOGY

The AFO's prototypes were made by Rapid Prototyping (RP) technology from the design and taking into account the improvements from FEM analysis. The several stereolithographic models were built in a Spectrum Z510 Color 3D Printers (Z Corporation-Burlington, USA), with zp130 powder and zb58 binder. The different stereolithographic models and the complete AFO's prototype are shown in figures 5a and 5b.

(a)

(b)

Figure 5 – Rapid Prototyping: (a) Prototypes of the AFO and (b) complete new ankle-foot orthosis prototype.

CONCLUSIONS

The light weight AFO developed has in consideration all the patient needs, and a new concept idea of orthosis, attended to achieve the standardization of all possible components, never forgetting that always exist some personalized components that are tailored for specific persons.

The design and concept development of a lightweight orthosis for the human lower limb that could comfortably provide plantar flexion and dorsiflexion energy during walking was accomplished.

With all the improvements that are achieved is possible to have a larger target of people with pathological gait using these innovative AFO's products, which could allows increasing their comfort.

Acknewlegment:

The authors would like to thanks to Fundação para a Ciência e Tecnologia the support of projects POCI/2010 and POCI/EME/60650/2004 "Prototipagem Rápida pelo Processo de Impressão 3D para o Desenvolvimento de Ferramentas e Próteses Médicas".

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